**Tribhuvan University**
**Institute of Science and Techonology**
**Bachelor of Science in Computer Science and Information Technology**
**Teachers Orientation Program**
**Paush 1-2, 2066**

**Course Title: Theory of Computation**
**Course no** : CSC-251 Full Marks: 80+20
**Credit hours** : 3 Pass Marks: 32+8

**Nature of course** : Theory (3 Hrs.) + Tutorials(3 Hrs)

**Course Synopsis:** Deterministic and non-deterministic finite state machines, regular expressions, languages and their properties. Context free grammars, push down automata, Turing machines and computability, undecidable and intractable problems, and Computational complexity.

**Goal**: To gain understanding of the abstract models of computation and formal language approach to computation.

**Course contents:**

**Unit 1:** **14 Hrs.**

1.1 **Review of Mathe matical Preliminaries** : 1 Hrs.

- Quick review of Sets, Logic, Functions, Relations, Languages, Proofs.

1.2 **Finite Automata** 7 Hrs

- Introduction of Finite State Machine
- Deterministic Finite Automata(DFA): Formal Definition, Notation of DFA, Extending the transition function of DFA, Language accepted by DFA
- Non-deterministic Finite Automata(NFA): Formal Definition, Notation, Extended transition function of NFA, Language of NFA, Equivalence of Deterministic and Non-deterministic Finite Automata-The Subset construction method, Theorems related to equivalence of DFA and NFA
- Finite Automata with Epsilon-Transition: Formal Definition, Notation, Extended Transition function of epsilon transition, Removing epsilon transition from epsilon NFA. Construction of DFA from epsilon NFA.
- Finite State Machine with output – Moore machine and Mealy machine-general concepts.

1.3 **Regular Expressions and Languages** 6 Hrs

- Introduction to regular operators, regular languages, Precedence of regular operators
- Regular expressions, Formal definition of regular expressions,
- Equivalence of Regular Expressions and Finite Automata. Theorem for conversion from regular expression to epsilon FA.
- Application of regular expressions
- Algebraic Laws for Regular Expressions.
- Properties of Regular Languages
  - Pumping Lemma and its Application
  - Closure properties of regular languages with proofs.
  - Decision properties of regular languages.- general concepts of decision properties, Minimization of Finite State Machine.

**Unit 2:**

**11 Hrs.**

2.1 **Context-Free Grammar** 6 Hrs

- Introduction to CFG, using grammar rules to describe a language, formal definition of CFG.
- Derivation using grammar – Bottom up and Top down approach, Left-most and Right- most derivation.
- The language of a Grammar, sentential form, derivation-tree, construction of parse-tree for a string from a grammar.
- Ambiguous grammar, inherent ambiguity, regular grammar.
- Equivalence of regular grammar and finite automata.
- Simplification of CFG.
- Normal Forms: Chomsky and Greibach Normal forms.
- Closure properties of Context Free Languages
- Pumping Lemma for Context Free Language – proving a language to be non-context free.

2.2 **Push Down Automata (PDA)** 5 Hrs

- Introduction, deterministic and non-deterministic PDA. Formal Definitions.
- Moves of PDA, Graphical representation of PDA, Instantaneous Description.
- Computation tree for PDA processing the input strings.
- Language of PDA- Acceptance by final state and by empty stack
- Conversion of PDA accepting by final state to accepting by empty stack and vice – versa.(theorems)
- Equivalence of PDA and CFG – conversion from CFG to PDA and vice –versa

**Unit 3:** **10 Hrs.**

**Turing Machines**

- Introduction to Turing Machines, Formal Definitions, Transition Diagram and transition table, Language of TM.
- Roles of TM – language recognizer, concept of TM as computing a function and enumerator of strings of languages.
- Computation by Turing Machines- Programming techniques viz. storage in a state, TM with multiple tracks, subroutines.
- Variants of Turing Machines – Multi-tape Turing Machine, Non-deterministic Turing Machines, Equivalence of one tape and multi- tape TM(related theorems), Concepts of Turing Enumerable Languages.
- Church's Thesis and Algorithm
- Universal Turing Machines
- Concept of Halting Problems
- Turing Machines and Computers- Simulating a TM by computer, simulating a real computer by a Turing Machine.

**Unit 4:** **10 Hrs.**

4.1 **Undecidability** 6 Hrs

- Concept of Recursive and Recursively Enumerable Languages.
- Encoding of Turing Machine, the diagonalization language, complements of RE language
- Proof of Universal Language theorem.
- Concepts of Unrestricted Grammars and Chomsky Hierarchy.
- Unsolvable Problems by Turing Machines.
- Undecidable Problems, Post's Correspondence Problems.

**4.2 Computational Complexity and Intractable Problems** 4 Hrs

- Measuring Complexity, Class P and Class NP
- Problems solvable in Polynomial time- Kruskal’s algorithm for minimum weight spanning tree.
- Non- deterministic Polynomial time- Problem TSP
- NP-Completeness and Problem Reduction
- NP-Complete Problems
- Introduction to Satisfiability Problem
- Normal Forms for Boolean Expressions

**Text Book:**

John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman, **Introduction to Automata Theory, Languages, and Computation,** Second Edition, Addison-Wesley, 2001. ISBN: 81-7808-347-7

**References:**

1. Efim Kinber, Carl Smith, **Theory of Computing: A Gentle introduction,** Prentice- Hall, 2001. ISBN: 0-13-027961-7.

2. John Martin, **Introduction to Languages and the theory of computation,** 3rd Edition, Tata McGraw Hill, 2003, ISBN:0-07-049939-X

3. Harry R. Lewis and Christos H. Papadimitriou, **Elements of the Theory of Computation**, 2nd Edition, Prentice Hall, 1998.

**Homework Assignments:**

Homework assignments will be given throughout the semester covering the lecture materials in each unit. The homework assignment will cover the 30% of the internal evaluation.

**Pre-requisite:** Discrete Mathematics, Fundamentals of Computer Programming and Data structure & algorithms.

**Evaluation and Grading:**

The evaluation and grading includes the 20% weitage for homework assignments and 2 mid term exam and 80 % weitage for final semester exam. The grading of the 20% internal evalua tion will be as:

Homework assignment: 30% (6 marks)
First Mid-term exam: 30% (6 marks)
Second Mid-term exam: 40% (8 marks)

Homework assignment will be given in at least each weekend.